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Floristic diversity in the Neogene and Modern forests of Pondicherry–Neyveli area of Tamil Nadu – its impact on climatic and phytogeographic aspects

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Abstract

The Neogene plant fossil (mega and micro) preserved abundantly in the sandstones around Pondicherry and the lignite deposits near Neyveli in the Cauvery basin of Tamil Nadu have been extensively studied over the last three decades. On the whole, 108 genera referable to 53 families of Angiosperms could be recognised in the Neogene flora of this region. Arecaceae is the predominant monocot family. Anacardiaceae, Barringtoniaceae, Clusiaceae, Combretaceae, Dipterocarpaceae and Fabaceae are numerically better represented among the dicots. The totality of the Neogene floral spectrum reveals the occurrence of discrete pockets of estaurine swamps at the coast line and tropical moist evergreen forest away from the coastal belt.

As against the tropical wet evergreen Neogene vegetational type, the present day Pondicherry-Neyveli area shows only few strands of vegetation consisting of scrub-woodlands or the so-called dry evergreen forests. The probable reasons for this dramatic change in the climate and vegetational types in the Neogene *vis a vis* the present day, along with the phytogeographic significance of some taxa are highlighted.

INTRODUCTION

The sandstone outcrops around Pondicherry and the vast lignite deposits at Neyveli are verily replete with a teeming multitude of varied plant fossils such as silicified and carbonized woods, mummified leaves and twigs and a galaxy of spore and pollen types of bewildering morphographic diversity. Over the last three decades these have been studied extensively resulting in a vast information that merits critical analysis and assessment of its relevance to our understanding of the Upper Tertiary vegetational complexes and climatic patterns.

Notwithstanding the great significance of the available knowledge of the Neogene Angiosperms *vis a vis* their modern counterparts, it is consistently glossed over by the students of extant plants. Among other things, this is attributable to the general apathy of the protago-

sists of Neobotany towards palaeobotanical data. The relationships of the Tertiary plant fossil with the modern taxa are inversely proportional to their geological age. The present survey utilizes collectively the data obtained from both palaeobotanical and palynological studies for a meaningful perspective of the Neogene floral assemblages.

GEOLOGICAL SET UP OF PONDICHERRY — NEYVELI AREA

Table1 provides information on the general geological succession of the area. The sedimentary regime spreading from Pondicherry to south of Rameswaram towards the Coromandel coast of Tamil Nadu represents the Cauvery main basin. The Pondicherry - Neyveli area lies in the Ariyalur-Pondicherry sub-basin. Detailed geological and geophysical investigations of this area were earlier carried out by Balasundar (1968), Kailasam (1968), Ramanathan (1968, 1979), Subramanyam (1969) and Gowrisankaran *et al.* (1987). The basement Precambrian horizon is succeeded by fossil-rich limestone, calcareous sandstone and marl of Ariyalur Formation (Upper Cretaceous). Highly fossiliferous marine Eocene sediments are found overlying the Ariyalur Formation in several borewells drilled in this sub-basin. The Mio-Pliocene Cuddalore Formation consisting of sandstones, clayey sandstones, sandy clay, and pockets of lignite, overlies unconformably the Eocene sediments. The Recent alluvium occupying the major part of the sub-basin tops the sequence (Table 1).

Table 1. General geological succession in the Pondicherry-Neyveli area
(After N. G. K. Murthy, 1968; Subramanyan, 1969)

Age	Formation	Lithology
Recent and subrecent		Soils, coastal sands, alluvium, laterite, kankar
Miocene (or Mio-Pliocene)	Cuddalore Formation	Argillaceous sandstone, lignite, pebble-bearing sandstone, grits, sands, clays
	Unconformity	
Eocene		Black clays, calcareous sandstones, fossiliferous limestone
	Unconformity	
Late Cretaceous	Ariyalur Formation	Shell limestones, shales, marl
	Unconformity	
Precambrian	Intrusives	Dolerites, pegmatites, charnockite, granitoid gneisses etc.

The sandstones around Pondicherry are coarse-grained or almost gritty, mottled and argillaceous with a generous dosage of ferruginous concretions and contain a profusion of silicified woods, many of them of respectful dimensions. The lignite embedded in the sandstone and seen essentially as one major seam in the vicinity of Neyveli shows rich and varied plant debris at various horizons.

Except in the environs of Tiruvakkarai about 13 miles WNW of Pondicherry, with an abundance of coniferous woods, the rest of the localities in the area show almost exclusively a wealth of silicified angiosperm woods. The coniferous woods at Tiruvakkarai are podocarpaceous and constitute virtually a pure strand of *Podocarpus*. Whether these podocarpaceous remains were from local floristic scenario or got transported from nearby hilly tracts seems to be a moot point.

The source material for the lignite deposit at Neyveli, however, was made up exclusively of angiosperm taxa with only a sprinkling of pteridophytic elements.

The present study is based essentially on angiosperm floristics in view of the overwhelming numerical preponderance of angiosperm taxa both in the standstone and lignite floral assemblages. Only such megafossils and palynomorphs which could be reliably referred to the extant taxa (genus and/or family) are considered in our survey.

NEOGENE AND MODERN FLORISTIC COMPOSITION AND VEGETATIONAL TYPES

Almost all the information of the Neogene plant fossils (mega and micro-) of the Pondicherry-Neyveli area has been generated at Birbal Sahni Institute of Palaeobotany, Lucknow and Osmania University, Hyderabad. As of today, 53 families of Angiosperms encompassing 108 genera could be recognized reliably (Table 2). Of these, 5 (Agavaceae, Arecaceae, Araceae, Poaceae and Potamogetonaceae) represent monocots, and 48 dicots. Arecaceae, numerically is the best represented family among the monocots. *Cocos, Eugeissona, Calamus, Sclerosperma* and *Livistona* are the palms that could be identified. Among the dicot families Anacardiaceae, Barringtoniaceae, Clusiaceae, Combretaceae, Dipterocarpaceae and Fabaceae (Caesalpiniodeae and Mimosoideae) are better represented.

Table 2. Angiosperms from the Neogene of Pondicherry-Neyveli area

Family	Fossil wood and related modern genus	Fossil pollen and related modern genus
AGAVACEAE	Carbonized stem *(Dracaena)*	
ALANGIACEAE	*Alangioxylon (Alangium)*	*Lonagiopollis (Alangium)*
ANACARDIACEAE	*Manigiferoxylon (Mangifera)* *Glutoxylon (Gluta)* *Bouea (Bouea)*	*Rhoipites*
ARALIACEAE		*Araliaceoipollenites (Aralia)*
ARECACEAE	*Palmoxylon (Livistona)*	*Palmaepollenites (Cocos)* *Arecipites* *Quilonipollenites (Eugeissona)* *Longapertites* *Proxapertites* *Dicolpopollis (Calamus)* *Trilatiporites (Sclerosperma)*
ARACEAE		*Spinainaperturites (Typhonium)*
AVICENNIACEAE		*Retitricolporites sitholeyi (Avicennia)*
BARRINGTONIACEAE	*Barringtonioxylon (Barringtonia)* *Careyoxlon (Careya)*	*Marginipollis (Barringtonia)*
BOMBACACEAE		*Bombacacidites* *Lakiapollis (Cullenia)*
BORAGINACEAE	*Cordioxylon (Cordia)*	
BRASSICACEAE		*Cruciferoipollenites*
CARYOPHYLLACEAE		*Polyporina*
CHENOPODIACEAE		*Polyporina globosa*
CLUSIACEAE	*Calophylloxylon (Calophyllum)* *Mesuoxylon (Mesua)*	*Pachydermites (Symphonia)* *Pentadesmapites (Pentadesma)*
COMBRETACEAE	*Terminalioxylon (Terminalia)* *Anogeissusoxylon (Anogeissus)*	*Heterocolpites (Lumnitzera)*

Floristic diversity in the Neogene and Modern forests

Family	Fossil wood and related modern genus	Fossil pollen and related modern genus
CTENOLOPHONACEAE		*Ctenolophonidites (Ctenolophon)*
DIPTEROCARPACEAE	*Dipterocarpoxylon (Dipterocarpus)* *Dryobalanoxylon (Dryobalanops)* *Anisopteroxylon (Anisoptera)* *Shoreoxylon (Shorea)* *Hopenium (Hopea)*	*Retitricolpites dipterocarpodies (Dipterocarpus)*
DROSERACEAE		*Droseridites*
EBENACEAE	*Ebenoxylon (Diospyros–Maba)*	
EUPHORBIACEAE	*Putranjivoxylon (Putranjiva)* *Bridelioxylon (Bridelia)*	*Crotonoidaepollenites (Jatropha)* *Crotonipollis*
FABACEAE	*Cynometroxylon (Cynometra)* *Milletioxylon (Milletia)* *Pterocarpoxylon (Pterocarpus)* *Pterogynoxylon (Pterogyne)* *Peltophoroxylon (Peltophorum)* *Pahudioxylon (Afzelia – Intsia)* *Tamarindoxylon (Tamarindus)* *Euacacioxylon (Acacia)* *Hopeoxylon (Sindora)* *Pericopsoxylon (Pericopsis)* *Albizinium (Albizia)*	*Margocolporites (Caesalpinia)* *Trisyncolpites (Poinciana, Caesalpinia)* *Palaeocaesalpinaceaepites* *Polyadopollenites (Acacia, Albizia)*
HALORAGACEAE		*Haloragacidites (Myriophyllum)*
HIPPOCRATEACEAE		*Hippocrateaceaedites* *Dakshinipollenites*

Family	Fossil wood and related modern genus	Fossil pollen and related modern genus
ICACINACEAE		*Icacinoipollenites*
LAMIACEAE		*Polycolpites*
LORANTHACEAE		*Gothanipollis*
LAURACEAE	*Litsea (Litsea)*	
LENTIBULARIACEAE		*Neyvelipollenites (Utricularia)*
LYTHRACEAE	*Lagerstroemioxylon (Lagerstroemia)*	*Verrutricolporites rotundiporis (Crenea)*
MENISPERMACEAE		*Assamialetes*
MORACEAE		*Triporopollenites (Artocarpus)*
NYMPHAEACEAE		*Monosulcites neyveliense (Nymphaea)*
ONAGRACEAE		*Triorites*
OLACACEAE		*Anacolosidites (Anacolosa)*
OLEACEAE		*Retitricolporites cuddalorense (Ligustrum)*
POACEAE		*Graminidites*
POTAMOGETONACEAE		*Retipilonapites (Potamogeton)*
PULMBAGINACEAE		*Warkallipollenites (Aegialitis)* *Plumbaginacipites*
POLYGALACEAE	*Xanthophyllum (Xanthophyllum)*	*Polygalacidites (Polygala)*
POLYGONACEAE		*Polygonacidites (Polygonum)*
PROTEACEAE		*Proteacidites (Isopogon)*
ROSACEAE	*Parinarioxylon (Parinari)*	
RUBIACEAE		*Palaeocoprosmadites (Coprosma)*
RHIZOPHORACEAE	*Carallioxylon (Carallia)*	*Zonocostites (Rhizophora)*
SAPOTACEAE	*Chrysophylloxylon (Chrysophyllum)*	*Sapotaceoidaepollenites*
SAPINDACEAE	*Sapindoxylon*	*Talisipites* *Cupanieidites (Cupania)*
SIMAROUBACEAE	*Ailanthoxylon (Ailanthus)*	
SONNERATIACEAE	*Sonneratioxylon (Sonneratia)*	*Florschuetzia (Sonneratia)*

Floristic diversity in the Neogene and Modern forests

Family	Fossil wood and related modern genus	Fossil pollen and related modern genus
	Dubangoxylon (Dubanga)	
STERCULIACEAE	*Sterculinium (Sterculia)*	*Tricollareporites (Pterospermum)*
SYMPLOCACEAE		*Symplocoipollenites (Symplocos)*
THYMELIACEAE		*Thymelaepollis Clavaperiporites (Wikstroemia)*
TILIACEAE	*Grewioxylon (Grewia)*	*Intratriporopollenites Lacrimapollis (Brownlowia)*
ULMACEAE	*Holoptelioxylon (Holoptelea)*	

(Data collected from : Agarwal, 1988, 1990a, 1990b, 1991a, 1991b; Ambawani, 1982; Lakhanpal & Awasthi, 1964; Awasthi, 1965, 1967, 1969a, 1969b, 1969c, 1970a, 1970b, 1971, 1974a, 1974b, 1975, 1977a, 1977b, 1979, 1980, 1981, 1984, 1986; Awasthi & Agarwal, 1986; Navale, 1956, 1959, 1964, 1973; Navale & Misra, 1979; Bande & Ambawani, 1982; Ramanujam, 1953a, 1953b, 1954, 1956a, 1956b, 1956c, 1958, 1960, 1961, 1966a, 1966b, 1966-67, 1968; Ramanujam & Rao, 1966, 1969; Ramanujam *et al.*, 1981; Ramanujam & Reddy, 1984; Ramanujam *et al.*, 1985; Reddy, 1981, 1989; Reddy *et al.*, 1984; Alpana Singh *et al.*, 1992).

There are a fairly good number of families which are represented by more than one fossil type i. e., silicified wood, carbonized wood, pollen, cuticle and mummified leaves. These are of considerable significance in any discussion on floristics. These families include Arecaceae, Dipterocarpaceae, Anacardiaceae, Ebenaceae, Rhizophoraceae, Clusiaceae, Combretaceae, Sonneratiaceae, Barringtoniaceae, Fabaceae, Sapotaceae, Euphorbiaceae and Thymeliaceae (Ramanujam, 1968; Awasthi, 1974b; Guleria, 1992; Srivastava, 1984; Upadhyay & Verma, 1986; Verma *et al.*, 1989; Agarwal, 1990b). The overall Neogene floristic spectrum of the Pondicherry-Neyveli area clearly signifies the occurrence of pockets of brackish water or estuarine mangrove swamps flush with the coast line and tropical wet evergreen forests away from the coastal belt (Ramanujam, 1982, 1990; Alpana Singh *et al.*, 1992). These two vegetational types reflect upon the then prevailing ecological conditions. The mangrove floral complexes could be found in the littoral regions between low and high tides at the river mouths where the soil is saline and mostly silty and clayey. *Rhizophora, Avicennia, Sonneratia, Barringtonia, Lumnitzera, Crenea, Aegialitis, Excoecaria* and *Brownlowia* constitute the mangrove taxa in the Neogene floras of the Pondicherry-Neyveli area.

Taxa which unequivocally point towards the prevalence of tropical wet evergreen forest, a product of warm climate and extreme humidity because of heavy precipitation all through the

year include *Gluta, Bouea, Calophyllum, Mesua, Pentadesma, Symphonea, Dipterocarpus, Dryobalanops, Anisoptera, Hopea, Diospyros, Ctenolophon, Cynometra, Milletia, Artocarpus, Anacolosa, Alchornia, Duabanga, Litsea, Parinari, Cullenia,* etc. (Champion & Seth, 1968; Puri *et al.*, 1983).

The members of Arecaceae are generally coastal and occupy a position away from the storm tide dominating the sandbeach flora. The deciduous taxa, viz., *Terminalia, Lagerstroemia, Anogeissus, Albizia, Cassia, Acacia, Sterculia,* etc. (Table 2) encountered along with the wet evergreens, must have occupied the more open segments in the evergreen forests apparently imparting a semi-evergreen look to these segments. When gaps are created accidentally in the otherwise dense evergreen forests resulting in relatively drier niches the deciduous elements from nearby regions creep in and get established. The generally hardy and more adaptable nature of these deciduous taxa would enable them to coexist locally with the evergreen ones. The occurrence of hydrophytic taxa such as *Nymphaea, Potamogeton, Myriophyllum* and *Utricularia* indicate the prevalence of local ponds. The few temperate members viz., *Symplocos, Ligustrum* and *Wikstroemia* encountered occasionally could have had their source in some uplands around the depositional site.

In comparison to the rich Neogene vegetational complex of tropical moist evergreen type, only few discontinuous patches of natural vegetation are now encountered in the Pondicherry-Neyveli area. These patches constitute the scrub woodlands/thickets or the so-called dry evergreen forests. The hilly ranges towards the west not far from the Pondicherry environs viz., Gingee, Tiruvannamalai, Tirukkovilur, Javadi, Chengam, etc. are clothed with dry deciduous forests. Many of the deciduous members of the Neogene floras continue to be represented in these forests. Under wetter climatic regime, however, of the Neogene times, these hilly ranges could have been occupied by moist evergreen vegetation. As against the warm humid climate of the Neogene period, the present day climate of the area is considerably dry and of dissymetric regime with the peak of rainfall during October-November months. Some rains (about 330 mm) no doubt, are received during the south-west monsoon season from June to September; but the bulk of the rain (about 800 mm), however, is during the north-east or retreating monsoon from October to January (Meher-Homji, 1974a, 1974b).

The scrub woodland formation shows taxa characteristic to it along with those seen commonly in the dry deciduous forests of the peninsula. The following are some of the more important taxa of this scrub jungle (for detailed information on this flora see Meher-Homji, 1974a; Puri *et al.*, 1983) : *Albizia amara, Manilkara hexandra, Pterospermum suberifolium, Atlantia monophylla, Garcinia spicata, Memecylon umbellatum, Maba buxifolia, Gmelina asiatica, Randia malabaricum, Grewia rhamnifolia, Sapindus emarginatus, Zizyphus xylopyrus, Chloroxylon swietinea, Albizia lebbek, Dalbergia paniculata, Dichrostachys cinerea, Flacourtia indica, Toddalia asiatica,* etc.

The occurrence of wet evergreen forest in the Pondicherry-Neyveli area now at a latitudinal position of about 12°N, could only be possible if this area was at the equatorial

latitude during the Miocene age (about 20 million yrs. ago). Incidentally as visualized by Meher-Homji (1976, 1978, 1980), the evidence from the northward drift of the Indian plate at 5–6 cm per year if worked backwards would put southern India at the equatorial latitude. As India moved from an equatorial position in Miocene to its present northern latitudinal position, it experienced considerable decline in rainfall. The dramatic deterioration in the climate from Neogene to the present day could also be attributable to the final phase of the Himalayan uplift manifested during Late Pliocene through Early Pleiostocene. It is during this final heave of the Himalayas that the monsoon pattern so characteristic of the Indian peninsula must have been firmly established resulting in drastic decline in the annual quantum of rainfall towards the Coromandel coast of southern India (Meher-Homji, 1980) which led to the disappearance of moist evergreen forest type leaving behind the deciduous ones. Further, the maximum elevation of the Western Ghats by the end of Pliocene effectively cut off the bulk of south-west monsoon from Coromandel coast (Meher-Homji, 1974b).

PHYTOGEOGRAPHIC CONSIDERATIONS

Most of the Neogene rain forest taxa of the Pondicherry-Neyveli region are now encountered in Kerala state and Western Ghats where the climate continues to be of the warm humid type with heavy precipitation. It is pertinent to note that these taxa were also recorded in the Neogene (Quilon and Warkalli beds) of Kerala (Guleria, 1992). *Gluta* (Anacardiaceae), *Dipterocarpus, Hopea* (Dipterocarpaceae), *Cynometra* (Caesalpinioideae), *Parinari* (Rosaceae), *Alchornia* (Euphorbiaceae), *Cullenia* (Bombacaceae), *Anacolosa* (Olacaceae), etc. as evidenced from their occurrence in the Neogene floras of various parts of India especially in north-eastern region (Guleria, 1992) seem to have enjoyed a much wider distribution during the Mio-Pliocene times compared to their present day restricted spread. Further, mention may particularly be made of some members viz., *Eugeissona (Quilonipollenites)* and *Sclerosperma (Trilatiporites)* of Arecaceae, *Anisoptera (Anisopteroxylon)* and *Dryobalanops (Dryobalanoxylon)* of Dipterocarpaceae, *Pentadesma (Pentadesmapites)* and *Symphonia (Pachydermites)* of Clusiaceae, *Bouea* of Anacardiaceae, *Sindora (Hopeoxylon)* of Fabaceae and *Ctenolophon (Ctenolophonidites)* of Ctenolophonaceae, which were recorded in the Neogene strata of the Pondicherry-Neyveli (and also of Kerala) region, but are conspicuous by their absence in the modern floras of India. *Eugeissona* is a coastal palm in Southeast Asia, and *Sclerosperma* is a tropical African palm. *Anisoptera* is now confined to the wet evergreen forests of Chittagong (Bângladesh), Burma, Malayan peninsula, Sumatra, Borneo and New Guinea. *Dryobalanops* is currently restricted to the rain forests of Sumatra, Borneo and Malayan peninsula. *Bouea* is another Malayan taxon. *Pentadesma* and *Symphonia* are essentially tropical African taxa, and lastly *Ctenolophon* is now seen in West Africa, and Malayan-Phillippine area.

The Malayan elements could have entered into India after the Indian plate established connection with Asian main land which seems to have happened during the Early Miocene. This was also the time when members of Dipterocarpaceae entered into India from their original home, the Malaysia.

The above conspectus thus clearly highlights that the Pondicherry-Neyveli area witnessed dramatic climo-vegetational changes from wet evergreen to deciduous to scrub woodland type since Mio-Pliocene times. In conclusion, it may be said that a meaningful study of the bygone floristics and vegetational complexes would add a new dimension and a new perspective to our understanding of the modern vegetational types.

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